FAN

Inventor: George EIMER

CROSS REFERENCE:

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FIELD OF THE INVENTION:

The present invention relates to a fan having an air conveying conduit and having a fan wheel arranged rotatably therein, the blades of which wheel are equipped, in the region of their external edges, with flow elements that have low resistance to the conveyed flow and that constitute an obstacle to the compensating flows proceeding around the outer edges of the blades from the delivery side to the intake side.

BACKGROUND:

A fan having such flow elements is known from the commonly assigned DE 30 17 226 A and corresponding GB 2 050 530-A, HARMSEN. These unexamined applications describe a variety of designs for such flow elements, in combination with fan blades stamped out of sheet metal. These flow elements reduce the leakage flow in a fan equipped therewith.

SUMMARY OF THE INVENTION:

It is an object of the invention to provide a new fan that exhibits a reduced noise level, at least in a predetermined operating range.

According to a first aspect of the invention, this object is achieved by a fan in which the fan blades are sickle-shaped and are provided, adjacent their tips, with flow-pattern obstacles which minimize air leakage between the intake side of the fan and the delivery side of the fan. It has been shown that, surprisingly, in such a fan the fan noise decreases, in particular, in the so-called laminar region, i.e. with high conveying volumes and a relatively small pressure rise $\Delta \mathbf{p}$. A noise reduction occurs with such a fan in the non-laminar region as well, i.e. with higher back pressures and smaller air quantities.

A theoretical explanation might be that an air flow occurs along the sickle-shaped front edges of the fan blades, and this air flow flows practically as far as the outer periphery of the hub, where the circumferential velocity is lowest, and consequently little noise is generated by this flow. The degree of sickling is, of course, limited by the fact that with a very pronounced sickle shape, the axial length of such a fan might become too great.

The stated object is achieved in another way by providing ends of the fan blades with flow elements which themselves are airfoil-shaped and which, in a middle region between their front and back edges, are wider than an adjacent part of the fan blade. It has been shown that this type of configuration of the profile of the blade and flow element contributes to particularly quiet running of the fan.

BRIEF FIGURE DESCRIPTION:

Further details and advantageous refinements of the invention are evident from the exemplifying embodiments, in no way to be understood as a limitation of the invention, that are described below and depicted in the drawings.

In the drawings:

FIG. 1 is a plan view of an equipment fan, in this case an axial fan, according to a first exemplifying embodiment of the invention;

FIG. 2 depicts the fan wheel of the fan of FIG. 1 in an enlarged depiction;

FIG. 3 is a three-dimensional depiction of the fan wheel according to FIGS. 1 and 2;

FIG. 4 is a side view of the fan wheel of FIGS. 1 to 3;

FIG. 5 is a section viewed along line V-V of FIG. 2;

FIG. 6 is a sagittal section through a blade of the fan of FIGS. 1 to 5, viewed along line VI-VI of FIG. 2;

FIG. 7 is a section viewed along line VII-VII of FIG. 2, in an enlarged depiction;

FIG. 8 is a section analogous to FIG. 7, viewed along line VIII-VIII of FIG. 2;

FIG. 9 is a section analogous to FIG. 7, viewed along line IX-IX of FIG. 2;

FIG. 10 is a depiction of the acoustic pressure level **Lp** and pressure increase Δ**p** plotted against the slider position of a test stand, for an axial fan whose fan blades have no flow elements on the outer edge;

FIG. 11 is a depiction analogous to FIG. 10, for a fan of the same construction but in which the fan blades are equipped on their outer edge with special flow elements;

FIG. 12 is a depiction comparing the curves in FIGS. 10 and 11; it is apparent that, with this exemplifying embodiment, a reduction in the acoustic pressure level **Lp** is obtained in particularly pronounced fashion in the laminar region, but also in the turbulent region;

FIG. 13 is a plan view, analogous to FIG. 2, of a fan wheel 122 according to a second embodiment of the invention;

FIG. 14 is a three-dimensional depiction of fan wheel 122 of FIG. 13 in a depiction analogous to FIG. 3; and

FIG. 15 is a comparative depiction showing fan characteristic curves for fan wheel 122 according to FIGS. 13 and 14, with and without the special flow elements (winglets).

DETAILED DESCRIPTION:

In the figures that follow, the same reference characters are used in each case for identical or identically functioning components, incremented by 100 if applicable (e.g. 122 instead of 22), and these components are usually described only once.

FIG. 1 shows an equipment fan 10 of ordinary design. The present invention can be implemented in an axial fan and, alternatively, in a diagonal fan. Fan 10, depicted in FIG. 1, has an external housing 12, at the four corners of which respective mounting openings 14 are provided and which defines in its interior an air conveying conduit 16, which conduit is limited toward the outside by a rotation surface 17 and in which conduit is rotatably mounted, via struts 18, the central hub 20 of a fan wheel 22 that, in operation, is rotated about a central axis 25 (FIGS. 4 and 5) by an electric motor arranged inside this hub 20. In FIG. 1, hub 20 rotates counterclockwise in the direction of an arrow 24. The air flow is such that the air is blown out over struts 18, i.e. through the back or "delivery" side of fan 10 with reference to FIG. 1.

As FIGS. 1 to 5 show, five fan blades 26, labeled 26A to 26E, are mounted on outer periphery 27 of hub 20. In this exemplifying embodiment, the angular distance **beta** (FIG. 2) from front edge 28A of fan blade 26A to front edge 28B of blade 26B is 74°. Blades 26 are distributed irregularly over the periphery of the hub in order to obtain a more pleasant frequency spectrum. The type of distribution depicted represents, of course, only a preferred embodiment.

As FIGS. 1 to 3 show, front edges 28A to 28E of blades 26 are embodied in concave and sickle-shaped fashion. The rear edges of blades 26 are labeled 36A to 36E, and are convex. They are implemented in such a way that their intersection with struts 18 occurs in "grazing" fashion, i.e. "with a grazing intersection." This means that, in most or all rotational positions and when viewed in plan, the imaginary intersection between a strut 18 and a rear edge 36 (which of course do not touch another) occurs at an angle as clearly shown, for example, in FIG. 1. This feature contributes to noise damping.

The radially outer edges of blades 26 are labeled 40A to 40E. As depicted in FIG. 5, these edges 40 are at a radial distance d from inner side 17 of external housing 12. This "air gap" **d** should be as small as possible. If it is large, a considerable leakage flow flows through it from the delivery side to the intake side of fan 10.

To reduce this air flow, the individual blades 26 are equipped in the region of their radially outer edges 40 with flow elements 42A to 42E, specifically with enlargements of outer blade edges 40, which enlargements preferably extend in the axial direction toward the intake side and the delivery side. (With diagonal fans, it is preferable to use blades on which such flow elements are present only on the intake side.)

As is evident from the sagittal sections of FIGS. 6 to 9, blades 26 have approximately the cross-sectional shape of an aircraft airfoil, i.e. front edge 28C is round and relatively blunt. From there, the thickness D (FIG. 6) of a blade 26 first increases and then decreases again toward rear edge 36, and blade 26 tapers to a sharp rear edge 36, in order to reduce or prevent the creation of eddies there, and consequently the creation of noise.

Flow elements 42 have an outline analogous to that of the associated blades (cf. FIG. 6), i.e. they likewise taper to a sharp rear edge 36 and are rounded at front edge 28; and in intermediate region 48 between the region of front edge 28 and the region of rear edge 36, they protrude beyond blade 26 by a substantially constant amount in the axial direction, as clearly shown by FIGS. 5 and 6. A smooth transition is provided at both ends, i.e. the constant amount smoothly decreases there to zero.

Flow elements 42, in combination with the narrow air gap **d** (FIG. 5), present an elevated resistance to the leakage flow that proceeds, during operation, around outer rim 40 of blades 26 from the delivery side to the intake side.

As is apparent in particular from FIGS. 3 and 4, the individual blades 26 are twisted, i.e. the location from which a blade 26, so to speak, "grows" out of hub 20 has approximately the shape of a screw-thread segment, and outer edges 40 of blades are likewise shaped in the manner of a screw-thread segment, although, as shown, the pitch of the screw-thread segments is greater in the region of hub 20 than in the region of the radially outer edges 40.

FIG. 10 shows the pressure rise Δ**p1** and acoustic pressure level **Lp1** for a fan whose blades 26 are not equipped with flow elements 42. The curves were measured on an ordinary fan test stand in which an adjustable throttle (not shown) is arranged on the delivery side of fan 10. The opening ODR of this throttle is indicated on the horizontal axis with values between 0 and 2500, "0" meaning that the throttle is closed.

It is apparent that for a throttle opening below 1000, fan 10 is working in the turbulent flow region, with the pressure Δ**p1** and acoustic pressure level **Lp1** rising toward the left.

For values to the right of the value of 1000 for the throttle opening, i.e. as the throttle is opened further, the pressure Δ**p1** decreases and the volume of air conveyed rises correspondingly, this being associated with a higher **Lp1**.

FIG. 11 shows curves for the exemplifying embodiment described here, i.e. the fan is the same as in FIG. 10 but fan wheel 22 is equipped with the above-described flow elements 42.

The profile of the pressure curve (Δ**p2**) is the same as in FIG. 10, but the acoustic pressure level **Lp2** is reduced by approximately 1.5 to 2 dB(A), especially in the region of larger throttle openings (approximately 1100 and up).

Curves **Lp1** and **Lp2** are largely coincident in the region around a throttle opening of 1000, but a drop in the acoustic pressure level is once again observable in the region below a throttle opening of 600.

The above-described flow elements 42 thus yield, without any additional effort, a reduction in acoustic pressure level **Lp** which is acoustically perceptible and whose magnitude depends on the working point at which the relevant fan 10 is operated. The sickling of front edges 28 likewise contributes to a diminution in noise.

FIGS. 13 and 14 show a fan wheel 122 according to a second, particularly preferred exemplifying embodiment of the invention, having a central hub 120. The external housing of this fan wheel has the same shape as external housing 12 of FIG. 1, and is therefore not depicted again. The rotation direction is labeled 124, i.e. fan wheel 122 rotates clockwise. FIG. 14 is a view toward the intake side of fan wheel 122.

As FIGS. 13 and 14 show, five fan blades 126 labeled 126A to 126E are mounted on outer periphery 127 of hub 120. Just as in the first exemplifying embodiment, these blades are distributed unevenly around periphery 127 of hub 120 in order to obtain a pleasant frequency spectrum for the fan noise.

As FIGS. 13 and 14 show, front edges 128A to 128E of blades 126 are concave and strongly sickle-shaped in configuration. In this exemplifying embodiment outer end 130A to 130E of sickles 128 is preferably located, when viewed in rotation direction 124, in front of transition point 132A to 132E of sickles 128 into hub 120; in particularly preferred fashion these transition points 132A to 132E are located all the way at the back with reference to rotation direction 124, i.e. the entire sickle 128 extends, as depicted, from this transition point 132 forward in the rotation direction.

This results, for example at transition point 132A, in a value of approximately 78° for the angle alpha at which sickle edge 128A emerges from hub 120. This angle alpha is, for example, greater than 90° in FIGS. 1 to 12,. It should preferably be less than 90° and has preferred values between 70 and 90°, in particular between 75 and 85°.

As explained below with reference to measurement curves, this configuration yields a considerable additional noise reduction, but usually requires a larger axial extension of the fan than with the version according to FIGS. 1 to 12.

For comparison, it should be noted that in the case of fan wheel 22 according to FIGS. 1 to 12, outer end 30A to 30E of sickles 28 is located in each case on the same radius vector as inner end 32A to 32E, which yields an axially shorter construction but is less favorable for noise reduction than the version according to FIGS. 13 to 15, as is evident from a comparison of the measurement curves according to FIG. 12 and FIG. 15.

The rear edges of blades 126A to 126E are labeled 136A to 136E and likewise have a more pronounced sickle-shaped curvature than in the version according to FIGS. 1 to 12. Their intersection with struts 18 of housing 12 once again occurs "with a grazing intersection," as described in detail with reference to FIGS. 1 to 12.

It should be noted, in this context, that for the version according to FIGS. 13 to 15, a shape was used for the external housing such that struts 18 extend in mirror-image fashion with respect to FIG. 1. For example, in FIG. 1 strut 18 extends from an outer point that would correspond to approximately 6 o'clock on a clock face to an inner point that corresponds to approximately 8 o'clock. In the version according to FIGS. 13 to 15, this strut would extend from an outer point corresponding to approximately 6 o'clock to an inner point that corresponds to approximately 4 o'clock. This results in the aforementioned "grazing intersection" for the fan wheels of FIGS. 13 and 14.

The outer radial edges of blades 126 are labeled 140A to 140E. Analogously to FIG. 5, these edges 140 are at a small radial distance d from the inner side of fan housing 12. Through the gap thereby formed, a leakage flow flows from the delivery side to the intake side of the fan.

To reduce this air flow, the individual blades 126 are equipped in the region of their radially outer edges 140 with flow elements 142A to 142E that extend in the axial direction between the intake side and delivery side.

The shape of flow elements 142 may be very easily gathered from the depiction of FIG. 14, which very clearly shows, in particular, flow element 142D and a portion of flow element 142C. The contour of flow elements 142 is the same as described in detail with reference to FIG. 6 for flow element 42C, and the same applies to the profile of blades 126, so that for this portion the reader may be referred to the description of FIGS. 1 to 12. In combination with the narrow air gap d (FIG. 5), flow elements 142 present an increased resistance to the leakage flow that proceeds, during operation, around outer rim 140 of blades 126 from the delivery side to the intake side.

As is clearly evident from FIG. 14, the individual blades 126 are twisted, i.e. the location from which a blade 126, so to speak, "grows" out of hub 120 has approximately the shape of a screw-thread segment, and outer edges 140 of blades 126 are likewise shaped in the manner of a screw-thread segment although, as depicted, the pitch is greater in the region of hub 120 than in the region of the radially outer edges 140.

FIG. 15 shows, in comparative fashion, fan characteristic curves for fan wheel 122 without flow elements and for fan wheel 122 with flow elements 142, with the same air gap **d** (as in the depictions of FIGS. 1 to 12). The pressure rise for a fan wheel without flow elements 142 is labeled **Δp3**, and the pressure rise for the same fan wheel 122 with flow elements 142 is labeled **Δp4**. It is apparent that a slightly greater pressure rise **Δp** is obtained without flow elements 142.

The acoustic pressure level for a fan wheel without flow elements is labeled **Lp3**, and the acoustic pressure level for the same fan wheel 122 with elements 142 is labeled **Lp4**. For this measurement, just as for FIGS. 1 to 12, the measurement microphone was located in front of the intake side of the fan at the axial height of the fan.

Comparing FIG. 15 with FIG. 12, it is evident that the greater sickling of front edges 128, in combination with flow elements 142, has resulted here in a reduction in the acoustic pressure level Lp over the entire measurement range, that reduction being very pronounced especially in the laminar region. For practical use, the noise reduction depends on the region of the relevant fan's characteristic curve in which it is operated, as is common knowledge among those skilled in the art of fans. A physical reason for the noise reduction might be that an air flow can form in the region of the sickle-shaped front edges 128 and flow along an entire front edge 128 from outside to inside, and thus to a region with a low circumferential velocity, flow elements 142 having a positive influence on the beginning of this air flow.

A measurement of the acoustic power **LWA** for the version according to FIGS. 13 to 15 has revealed that, particularly in the range of the middle-third frequencies from 5 to 20 kHz, it was possible to achieve a reduction in acoustic power as a result of the flow elements. In the region from 160 to 4000 Hz, on the other hand, the acoustic power values differ only slightly, i.e. it is rushing noise in particular that is reduced by flow elements 42 and 142.

Many variants and modifications are, of course, possible within the scope of the present invention.